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**Impact of red and processed meat and fibre intake on treatment outcomes among patients with chronic inflammatory diseases  
protocol for a prospective cohort study of prognostic factors and personalised medicine**

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# BMJ Open Impact of red and processed meat and fibre intake on treatment outcomes among patients with chronic inflammatory diseases: protocol for a prospective cohort study of prognostic factors and personalised medicine

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## ABSTRACT

**Introduction** Chronic inflammatory diseases (CIDs) are frequently treated with biological medications, specifically tumour necrosis factor inhibitors (TNFi). These medications inhibit the pro-inflammatory molecule TNF alpha, which has been strongly implicated in the aetiology of these diseases. Up to one-third of patients do not, however, respond to biologics, and lifestyle factors are assumed to affect treatment outcomes. Little is known about the effects of dietary lifestyle as a prognostic factor that may enable personalised medicine. The primary outcome of this multidisciplinary collaborative study will be to identify dietary lifestyle factors that support optimal treatment outcomes.

**Methods and analysis** This prospective cohort study will enrol 320 patients with CID who are prescribed a TNFi between June 2017 and March 2019. Included among the patients with CID will be patients with inflammatory bowel disease (Crohn's disease and ulcerative colitis), rheumatic disorders (rheumatoid arthritis, axial spondyloarthritis, psoriatic arthritis), inflammatory skin diseases (psoriasis, hidradenitis suppurativa) and non-infectious uveitis. At baseline (pretreatment), patient characteristics will be assessed using patient-reported outcome measures, clinical assessments of disease activity, quality of life and lifestyle, in addition to registry data on comorbidity and concomitant medication(s). In accordance with current Danish standards, follow-up will be conducted 14–16 weeks after treatment initiation. For each disease, evaluation of successful treatment response will be based on established primary

## Strengths and limitations of this study

- This study includes a number of diseases treated with biologics, targeting the pro-inflammatory cytokine tumour necrosis factor alpha.
- All evaluations will be performed as part of a prospectively designed cohort study using established disease-specific scoring systems.
- As comparisons between diseases are limited by disease-specific scoring systems, additional response criteria (eg, quality of life and disability) will be used for analysis.
- The sample size is limited.

and secondary endpoints, including disease-specific core outcome sets. The major outcome of the analyses will be to detect variability in treatment effectiveness between patients with different lifestyle characteristics.

**Ethics and dissemination** The principle goal of this project is to improve the quality of life of patients suffering from CID by providing evidence to support dietary and other lifestyle recommendations that may improve clinical outcomes. The study is approved by the Ethics Committee (S-20160124) and the Danish Data Protecting Agency (2008-58-035). Study findings will be disseminated through peer-reviewed journals, patient associations and presentations at international conferences.

**Trial registration number** NCT03173144; Pre-results.

## INTRODUCTION

Chronic inflammatory diseases (CIDs) are a diverse set of immunological diseases that include inflammatory bowel disease (IBD) (Crohn's disease (CD) and ulcerative colitis (UC)), rheumatic conditions (rheumatoid arthritis (RA), axial spondyloarthritis (axSpA), psoriatic arthritis (PsA)), inflammatory skin diseases (psoriasis (PsO), hidradenitis suppurativa (HS)) and eye disease (non-infectious uveitis (NiU)). The pro-inflammatory cytokine tumour necrosis factor  $\alpha$  (TNF) is recognised to play an important role in the aetiology of these diseases. Correspondingly, biological agents that inhibit TNF, also known as TNF inhibitors (TNFi), are an important component of treatment. However, a large number of patients do not benefit from TNFi treatment.<sup>1</sup>

CIDs have a large and negative impact on both individual patients and at a community level as a consequence of health-related workplace productivity loss and health system expense, which is largely influenced by the high cost of providing biological medications.<sup>1</sup> CIDs are recurring, lifelong illnesses of potentially early onset that can substantially affect the life quality of patients and their families.<sup>2-5</sup> In addition, they are prevalent diseases with IBD affecting 0.5% of the population in the Western world,<sup>6</sup> and RA and PsO affecting respectively 0.3%–1.0% and 1.5% of the global population.<sup>7,8</sup> Furthermore, the disease burden, and hence health system burden, is predicted to rise dramatically due to population growth, ageing demographics and increasing disease incidence.<sup>9-11</sup>

The diseases may have overlapping symptoms.<sup>12</sup> For example, some patients with NiU and axSpA may experience bowel symptoms, and some patients with IBD may develop extraintestinal manifestations (ie, eye, joint and skin symptoms). The diseases are rather complex with both genetic and environmental factors implicated in aetiology. While CIDs share some genetic and environmental predisposing factors, other susceptibility factors differ.<sup>13</sup> The genetic architecture of CIDs has previously been investigated by large international consortia.<sup>14-20</sup> Similarly, environmental factors have been investigated in large cohorts with prospectively collected lifestyle data, such as the European Investigation into Cancer and Nutrition Study as well as the Nurses' Health Study.<sup>21-35</sup>

In light of the notable impact that environment factors play in disease development, which is further supported by the increasing incidence of these disease,<sup>6,11</sup> it stands to reason that modifying environment factors such as lifestyle may influence treatment response. Accordingly, quite a few patients ask their healthcare professionals for lifestyle recommendations that can influence the effectiveness of treatment, and in particular the outcomes achieved with TNFi.

## Evidence-based research

In an attempt to increase value and reduce waste in research, a systematic review of existing evidence was performed prior to embarking on this study.<sup>36</sup> In a recent

systematic review examining the impact of diet on TNFi response in IBD,<sup>37</sup> it was concluded that there is scarce evidence linking TNFi treatment response to specific dietary recommendations; hence, there is a clear research need. Similarly, only a few large prospective studies have assessed the effects of lifestyle on TNFi-treated patients with CID.<sup>38</sup> One prospective study compared partial enteral nutrition (16 patients), exclusive enteral nutrition (22 patients) and TNFi (52 patients) therapy in 90 paediatric patients. There were no significant differences in clinical response rates between the three treatment arms, although the rate of patients that achieved a faecal calprotectin concentration of  $\leq 250 \mu\text{g/g}$  was higher among the TNFi-treated patients.<sup>39</sup>

More recently, lifestyle factors, as they relate to TNFi therapy among patients with CID, were identified as an area for further investigation.<sup>40</sup> To explore different hypotheses, we included studies that may be subject to recall bias or bias introduced by lifestyle changes due to the disease itself, for example, smoking, physical activities and intake of Western-style diet.<sup>40</sup> After reviewing these potential hypotheses, we proposed a model, whereby a diet high in meat and low in fibres may impact inflammation and TNFi treatment<sup>37</sup> (figure 1).

Based on previous evidence, we set out to prospectively identify dietary factors that support optimal TNFi treatment outcomes, with the ultimate aim of improving the quality of life of patients with CID.

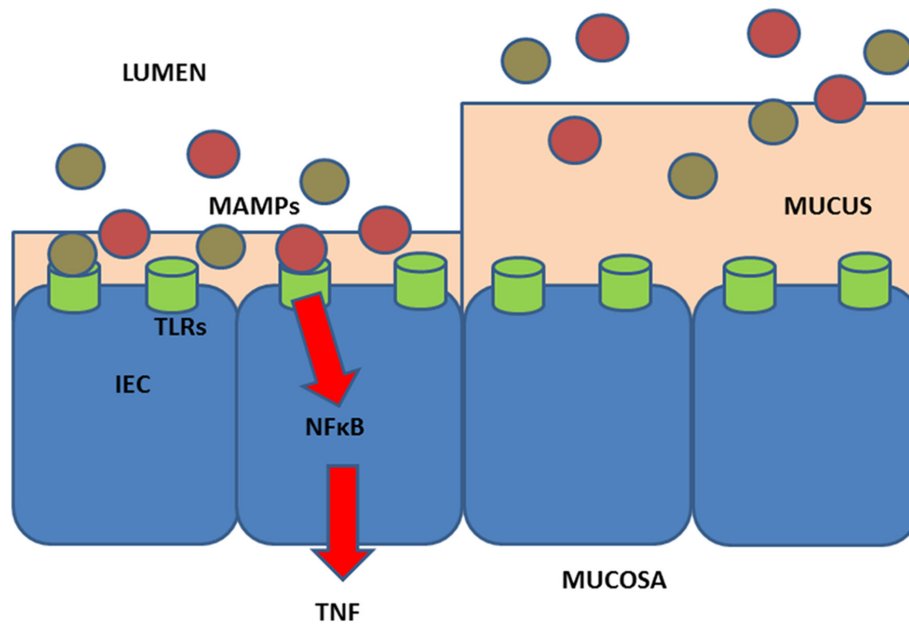
## Aims and hypotheses

The primary aim of this prospective cohort study is to investigate whether treatment outcomes in patients with CID vary with dietary differences. The main hypothesis is that 'Diets high in fibre AND low in red and processed meat are associated with improved treatment outcomes'. Secondary aims are whether and to what extent lifestyle-associated biomarkers have prognostic value for differentiating responders from non-responders based on both disease-specific and generic treatment outcomes.

## METHODS AND ANALYSES

### Design

This study is a prospective cohort study that will examine disease activity after initiating TNFi treatment. The primary endpoint will be assessed 14–16 weeks after initiation of a TNFi and will be defined based on the specific CID condition. The cohort will be classified as responders (including those who continue with drug treatment) or non-responders (including those who discontinue drug treatment) based on the disease-specific criteria defined below. The decision to discontinue therapy is assumed to be based on a shared decision-making process between patients and their physicians and to be supported by principles outlined in disease-specific guidelines.<sup>41</sup>



**Figure 1** Hypothesis for effects of diet in relation to treatment effect. (Left) Low levels of fibre intake may promote microbial metabolism of mucus as the main energy source.<sup>37 75 76</sup> This will lead to decrease of the mucus layer. Further, degradation of mucus releases free sulfate, which would then become available for use by sulfate-reducing bacteria (eg, *Bilophila wadsworthia*) for microbial produced hydrogen sulfide.<sup>77</sup> In addition, high intake of food containing organic sulfur and sulfate additives, such as meat and processed meat, may increase the amount of sulfate for microbial produced hydrogen sulfide.<sup>78 79</sup> The resultant hydrogen sulfide from low intake of fibre and high intake of meat may reduce the disulfide bonds in the mucus network rendering the mucus layer penetrable to, for example, bacteria.<sup>77 80</sup> Then, MAMPS from microbes or contained in the diet may reach the epithelium and activate the pattern recognition receptors such as TLRs on the enterocytes (IEC) and next activate NFκB, type I interferon and other inflammatory pathways. This leads to production of pro-inflammatory (TNF, IL-1β, IL-6, IFN, IL-17, etc), and anti-inflammatory (primarily IL-10) cytokines and chemokines that will next activate innate lymphocytic cells and other immune cells and the immune system in general.<sup>81 82</sup> There is some support for such a mechanism in chronic inflammatory disease, including findings of high amounts of sulfate-reducing bacteria in patients with UC<sup>77 83</sup>; an association between the highest tertile of carbohydrate-restricted diet and RA, in a nested case-control study among 386 individuals who developed RA and 1886 matched controls from the Swedish Västerbotten Intervention Program cohort with prospectively sampled dietary survey<sup>84</sup>; association of high-fibre intake with low risk of Crohn's disease among 170 776 participants from the prospective Nurses' Health Study I<sup>23</sup>; association of high intake of red meat and total protein and risk of developing inflammatory polyarthritis in the population-based prospective cohort of 25 630 participants from the European Prospective Investigation of Cancer in Norfolk.<sup>35</sup> Finally, a prospective study of 191 patients with UC in remission found that high consumption of meat, particularly red and processed meat, protein and alcohol was associated with risk of relapse, and that high sulfur or sulfate intakes may offer an explanation for the observed findings.<sup>85</sup> Additionally, support of the notation that diet may affect systemic immune response is provided by the finding that intake of low glycaemic index diet was found to lower secretion of TNF and IL-6 from stimulated peripheral blood mononuclear cells from obese humans.<sup>86</sup> (Right) Intake of high fibre and low meat may promote an effective mucosal barrier and support the effects of outcome after drug targeting the pro-inflammatory molecule TNF (TNF inhibitors). Intake of soluble plant fibre has been found to block bacterial adhesion to gut enterocytes in animal and cell studies.<sup>87</sup> The genetic architecture of the individual may also impact the influence of lifestyle factors.<sup>15</sup> Hence, to provide lifestyle recommendations, we need to understand the effects of lifestyle on the immune system and how lifestyle may improve the therapeutic outcome and reduce the need of medical treatment in the individual person. Information on diet and non-diet lifestyle exposures may be collected by using, for example, questionnaires and lifestyle-associated biomarkers or a combination of these methods.<sup>88–90</sup> Evidence-based biomarkers for lifestyle assessment are scarce<sup>91–111</sup> and mostly used for studies on healthy individuals.<sup>112–115</sup> IEC, intestinal epithelial cells; IL, interleukin; MAMPS, microbial-associated molecular patterns; NFκB, nuclear factor kappa B; RA, rheumatoid arthritis; TLR, Toll-like receptors; TNF, tumour necrosis factor; UC, ulcerative colitis.

## Setting

This multicentre study reflects a collaboration between the following centres: (1) Department of Gastroenterology and Hepatology, Aalborg University Hospital; (2) Department of Hepatology and Gastroenterology, Aarhus University Hospital; (3) Diagnostic Centre, Silkeborg Regional Hospital; (4) Department of Internal Medicine, Herning Regional Hospital; (5) Department of Gastroenterology, Herlev Hospital; (6) Organ Centre, Hospital

of Southern Jutland; (7) Department of Gastroenterology, Hospital of South West Jutland; (8) Department of Medical Gastroenterology, Department of Rheumatology, Department of Dermatology and Allergy Centre and Department of Ophthalmology, Odense University Hospital. Study enrolment will take place between 15 June 2017 and 31 March 2019 or until the study has enrolled a minimum of 100 patients with IBD, 100 patients with RA and 120 patients with axSpA, PsA, PsO, HS and NiU.



### Patient characteristics and eligibility criteria

Inclusion criteria: patients  $\geq 18$  years with CID who are beginning TNFi therapy, who have not previously received TNFi treatment and who are able to read and understand Danish. Exclusion criteria: patients who have previously received a biological treatment and patients who by virtue of illiteracy or cognitive impairment are unable to complete the questionnaire.

Clinical data (table 1) will include personal data, data on health and disease, dietary and non-dietary lifestyle information, laboratory measurements and disease activity scores including patient-reported outcome measures (PROMs), clinical assessments and laboratory data. Participants will complete validated questionnaires on disease activity, quality of life and lifestyle using an electronic link. Studies have revealed electronic questionnaires to be comparable to paper based in relation to the outcomes (ie, PROMs).<sup>42 43</sup>

### Primary and secondary endpoints

#### Primary endpoint

The predefined primary endpoint will be the proportion of patients with a clinical response to therapy 14–16 weeks after treatment initiation. Below are the disease-specific definitions of clinical response to therapy:

- ▶ Crohn's disease: clinical remission, defined as Harvey-Bradshaw Index (HBI) of 4 or less;<sup>44</sup>
- ▶ Ulcerative colitis: clinical remission, defined as Mayo Clinic Score of 2 or less (with no individual subscore of  $>1$ );<sup>45</sup>
- ▶ rheumatoid arthritis: clinical response, defined as at least a 20% improvement according to the criteria of the American College of Rheumatology (ACR20);<sup>46</sup>
- ▶ axial spondyloarthritis: clinical response, defined as at least a 20% improvement according to the Assessment of Spondyloarthritis International Society (ASAS20);<sup>47 48</sup>
- ▶ psoriatic arthritis: clinical response, defined as at least a 20% improvement according to the criteria of ACR20;<sup>49</sup>
- ▶ psoriasis: clinical response, defined as at least a 75% improvement in Psoriasis Area and Severity Index (PASI 75);<sup>50</sup>
- ▶ hidradenitis suppurativa: clinical response, defined as at least a 50% reduction in the abscess and inflammatory-nodule count, with no increase in abscess or draining-fistula counts (HiSCR response);<sup>51</sup>
- ▶ non-infectious uveitis: clinical response, defined as those who did not have a treatment failure (treatment failure will be based on assessment of new inflammatory lesions, best-corrected visual acuity, anterior chamber cell grade and vitreous haze grade).<sup>52</sup>

#### Key secondary outcomes

Major secondary outcomes, also to be measured 14–16 weeks after treatment initiation, include disease-specific outcome measures that cover core outcome sets, the generic health-related quality of life (HRQoL) and

disability at endpoint. Below are a list of disease-specific secondary outcomes.

- ▶ CD: Selecting Therapeutic Targets in Inflammatory Bowel Disease (STRIDE; abdominal pain, diarrhoea, altered bowel habit, SES-CD (presence of ulcers, ulcerated surface, affected surface, presence of narrowing, number of affected segments), alterations of cross-sectional imaging (MR, CT, ultrasound) (only when endoscopy cannot adequately evaluate inflammation)), HBI (general well-being, abdominal pain, number of liquid stools per day, abdominal mass, extraintestinal manifestations (abscess, fistulas, fissures, arthralgia, uveitis, erythema nodosum, pyoderma gangrenosum, mouth ulcers)), physician global assessment, number of draining fistulas, corticosteroid-free remission, concomitant medication.
- ▶ UC: STRIDE (rectal bleeding, altered bowel habit, endoscopic remission (Mayo endoscopic subscore of 0–1)), Mayo Clinical Score (Mayo endoscopic subscore, stools, rectal bleeding, physician global assessment), Mayo 'normal mucosal appearance', Mayo clinical response, Simple Clinical Colitis Activity Index (bowel frequency (day), bowel frequency (night), urgency of defecation, blood in stool, general well-being, extracolonic features), physician global assessment, corticosteroid-free remission, concomitant medication.
- ▶ RA: Tender joints, swollen joints, pain, physician global assessment, patient global assessment, Health Assessment Questionnaire (HAQ), C reactive protein (CRP), Disease Activity Score (DAS)28-CRP, Simplified Disease Activity Index (SDAI).
- ▶ Axial spondyloarthropathy: Bath Ankylosing Spondylitis Metrology Index (BASMI), Bath Ankylosing Spondylitis Functional Index (BASFI), Bath Ankylosing Spondylitis DAI, total score for back pain, physician global assessment, patient global assessment, CRP.
- ▶ Psoriatic arthritis: tender joints, swollen joints, psoriatic arthritis pain, physician global assessment, patient global assessment, HAQ-DI, CRP, DAS28-CRP, SDAI, PASI.
- ▶ Psoriasis: PASI, physician global assessment, patient global assessment, psoriatic arthritis pain, Dermatology Life Quality Index total score.
- ▶ Hidradenitis suppurativa: percentage of participants who achieve abscess and inflammatory nodule (AN) count of 0, 1 and 2, respectively, patient's global assessment of skin pain, modified Sartorius score.
- ▶ Non-infectious uveitis: new active, inflammatory chorioretinal or retinal vascular lesions relative to baseline, inability to achieve  $\leq 0.5+$  or a two-step increase relative to the best state achieved at all visits in anterior chamber cell grade or vitreous haze grade, worsening of best-corrected visual acuity by  $\geq 15$  letters relative to best state achieved.

**Table 1** Collection of patient characteristics, outcome measures and explanatory variables

Variable	Pre	Week 14–16
<b>Clinical data*</b>		
Gender (F, M)	X	
Age (years)	X	
Diagnosis (disease)	X	
Onset of diagnosis (year) <sup>†</sup>	X	
Education (level) <sup>‡</sup>	X	
Menopause (year)	X	
Comorbidity (diseases, Charlson index)	X	
Medication (predefined choices)	X	X
Diet (FFQ) (predefined choices)	X	
Changes in diet (predefined choices)		X
Non-dietary lifestyle factors <sup>‡</sup> (predefined choices)	X	X
<b>Investigations:</b>		
Height (cm)	X	
Weight (kg)	X	X
Body mass index (kg/m <sup>2</sup> )	X	X
Routine blood analyses <sup>§</sup>	X	X
Endoscopy <sup>¶</sup>	X	X
<b>Biological samples**</b>		
Fasting blood samples	X	X
Faeces samples	X	X
Urine samples	X	X
Biopsies <sup>¶</sup>	X	X
<b>CD</b>		
Disease location (predefined choices)	X	
Prior operations (y/n, description)	X	
Disease behaviour (fistulising, luminal)	X	
Perianal involvement (y/n)	X	
STRIDE—(y/n)	NA	X
Abdominal pain (y/n)	X	X
Diarrhoea (y/n)	X	X
Altered bowel habit (y/n)	X	X
SES-CD (score)	X	X
Presence of ulcers (score)	X	X
Ulcerated surface (score)	X	X
Affected surface (score)	X	X
Presence of narrowing (score)	X	X
Number of affected segments (score)	X	X
Alterations of cross-sectional imaging (MR, CT, UL) (y/n) <sup>††</sup>	X	X
HBI index (score)	X	X
HBI of 4 or less (y/n) <sup>‡‡</sup>	X	X
General well-being (score)	X	X
Abdominal pain (score)	X	X
No of liquid stools per day (N)	X	X

Continued

Table 1 Continued

Variable	Pre	Week 14–16
Abdominal mass (score)	X	X
Manifestations (abscess, fistulas, fissures, arthralgia, uveitis, erythema nodosum, pyoderma gangrenosum, mouth ulcers, one point for each) (N)	X	X
Physician global assessment (score)	X	X
Physician global assessment (0–100 mm VAS)	X	X
Patient global assessment (0–100 mm VAS)	X	X
Corticosteroid-free remission§§ (y/n)		X
Concomitant medication (y/n, predefined choices)	X	X
Number of draining fistulas (fistulising CD)	X	X
UC		
Disease location (predefined choices)	X	
Prior operations (y/n, description)	X	
STRIDE criteria (y/n)	NA	X
Rectal bleeding (y/n)	X	X
Altered bowel habit (y/n)	X	X
Endoscopic remission (Mayo endoscopic subscore of 0–1)	X	X
Mayo clinical score of 2 or less with no individual subscore of >1‡‡	X	X
Mayo ‘normal mucosal appearance’ (y/n)	X	X
Mayo clinical response§§ (y/n)¶¶	X	X
Mayo clinical score (score)	X	X
Mayo endoscopic subscore (score)	X	X
Stools (score)	X	X
Rectal bleeding (score)	X	X
Physician global assessment (score)	X	X
SCCAI (score)	X	X
Bowel frequency (day) (score)	X	X
Bowel frequency (night) (score)	X	X
Urgency of defecation (score)	X	X
Blood in stool (score)	X	X
General well-being (score)	X	X
Extracolonic features (one per manifestation)	X	X
Physician global assessment (0–100 mm VAS)	X	X
Patient global assessment (0–100 mm VAS)	X	X
Corticosteroid-free remission§§ (y/n)		X
Concomitant medication (y/n, predefined choices)	X	X
Rheumatoid arthritis		
Positive for anti-CCP/RF (y/n)	X	
Swollen joint count (of 28/66 joints examined)	X	X
Tender joint count (of 28/68 joints examined)	X	X
DAS28-CRP (score)	X	X
SDAI (score)	X	X
ACR20 (y/n)‡‡	NA	X
ACR50 (y/n)	NA	X
ACR70 (y/n)	NA	X

Continued

**Table 1** Continued

Variable	Pre	Week 14–16
EULAR good or moderate response (y/n)	NA	X
Low disease activity (DAS28<3.2)	NA	X
DAS28 remission (DAS28<2.6)	NA	X
Physician global assessment (0–100 mm VAS)	X	X
Patient global assessment (0–100 mm VAS)	X	X
Patient assessment of pain (0–100 mm VAS)	X	X
HAQ (score)	X	X
axSpA		
Positive for HLA-B27 (y/n)	X	
BASDAI (score)	X	X
BASFI (score)	X	X
BASMI (score)		
Total score for back pain (0–100 mm VAS)	X	X
Patient global assessment of disease activity (0–100 mm VAS)	X	X
Patient assessment of pain (0–100 mm VAS)	X	X
Physician global assessment (0–100 mm VAS)	X	X
ASAS20 (y/n)††	NA	X
ASAS40 (y/n)	NA	X
ASAS partial response (y/n)	NA	X
ASAS5/6 response (y/n)	NA	X
PsA		
Dactylitis (y/n)	X	X
Enthesitis (y/n)	X	X
PASI (score)	X	X
PASI 75 response (y/n)	NA	X
PASI 90 response (y/n)	NA	X
ACR20††	NA	X
Swollen joint count (of 28/66 joints examined)	X	X
Tender joint count (of 28/68 joints examined)	X	X
DAS28-CRP (score)	X	X
Patient global assessment of disease activity (0–100 mm VAS)	X	X
Patient assessment of PsA pain (0–100 mm VAS)	X	X
Physician global assessment (0–100 mm VAS)	X	X
SDAI	X	X
HAQ (score)	X	X
PsO		
Psoriatic arthritis (y/n)	X	X
PASI (score)	X	X
PASI75 response (y/n)††	NA	X
PASI90 response (y/n)	NA	X
Patient global assessment of disease activity (0–100 mm VAS)	X	X
Patient assessment of PsA pain (0–100 mm VAS)	X	X
Physician global assessment (0–100 mm VAS)	X	X

Continued



**Table 1** Continued

Variable	Pre	Week 14–16
DLQI (score)	X	X
Hidradenitis suppurativa		
HiSCR response $\ddagger\ddagger$	NA	X
Hurley stage*** (score)	X	X
Previous systemic treatment (y/n, description)	X	
Prior surgery (y/n, description)	X	
Lesion counts (N)	X	X
Total no. of abscesses and inflammatory nodules (N)	X	X
No. of abscesses (N)	X	X
No. of inflammatory nodules (N)	X	X
No. of draining fistulas (N)	X	X
Modified Sartorius score (score)	X	X
Percentage of participants who achieve abscess and inflammatory nodule (AN) count of 0, 1 and 2, respectively	X	X
Patient global assessment of skin pain (score)	X	X
DLQI (score)	X	X
NiU		
SUN (score)	X	X
Uveitis treatment failure (y/n) $\ddagger\ddagger$	NA	X
New active, inflammatory chorioretinal or retinal vascular lesions relative to baseline (y/n)	X	X
Inability to achieve $\leq 0.5+$ or a two-step increase relative to best state achieved at all visits in anterior chamber cell grade or vitreous haze grade (y/n)	X	X
Worsening of best-corrected visual acuity by $\geq 15$ letters relative to best state achieved (y/n)	X	X
Health-related quality of life $\dagger\dagger\dagger$	X	X
SF12 (score)	X	X
SHS (score)	X	X
Physician global assessment (0–100 mm VAS)	X	X
Patient global assessment (0–100 mm VAS)	X	X
Rome-III (score)	X	X
NYHA (score)	X	X
Continuation of anti-TNF treatment (y/n, predefined choices for stopping if no)	X	X
Adverse events		
Discontinuation due to adverse events (y/n)		X
Serious adverse event (y/n)		X
Death (y/n)		X
Occurrence of surgery (y/n)		X
Occurrence of hospital admission (y/n)		X
Occurrence of disease-related complication (y/n)		X
Laboratory $\S$		
CRP (mg/L) $\ddagger\ddagger\ddagger$	X	X

Continued



Table 1 Continued

Variable	Pre	Week 14–16
*Data will be collected using a questionnaire as well as local and national registries.		
†Registry data will be retrieved from the Danish registries using the Danish individual civil registration number (CPR) including BIO-IBD, <sup>116</sup> DANBIO, <sup>117</sup> DERMBIO <sup>118</sup> (database on IBD, RA, HS, axSpA, PsA and PsO patients on biological therapy), the National Patient Registry (eg, comorbidity), registries on medication and use of receipts, local laboratory databases (laboratory data) and the electronic patient records (side effects).		
‡Lifestyle (dietary and non-dietary) will be registered using a validated FFQ that includes food items and a photographic food atlas of picture series of portion sizes will be used to assess intake of food groups, such as meat and dairy, and calculate total energy, fibre, protein, fat, sugar and carbohydrate intakes as well as glycaemic index and load. In addition, questions on non-diet lifestyle factors (smoking, physical activity, alcohol consumption and use of over-the-counter medicine (use of probiotics, prebiotics, painkillers, laxative and antidiarrhoea agents)) as well as educational level and year of menopause (female) are included. <sup>63</sup> The follow-up questionnaire is identical to the initial questionnaire apart from the questions on food items that only contain questions on changes of diet since the last questionnaire.		
§Routine blood analyses include CRP, haemoglobin, erythrocyte count, haematocrit, erythrocyte mean cell volume, mean cell haemoglobin and mean cell haemoglobin concentration, leucocyte count, differential count, thrombocytes, K+, Na+, creatinine, coagulation factor II+VII+X, alanine aminotransferase, alkaline phosphatase, gamma-glutamyl transferase, haemoglobin glycation, lipids (cholesterol, high-density, low-density cholesterol) and transglutaminase.		
¶Only patients with IBD.		
**From all participants, blood, urine and faeces are sampled. In addition, from patients with IBD, intestinal biopsies are sampled. In selected cases, the additional biological material on participants from this study may be retrieved from the Patobank and the Danish Biobank. The samples will be collected adhering to the Sample PRE-analytical Code and Biospecimen Reporting for Improved Study Quality guidelines, using standard operational procedures describing and logging primary container, centrifugation conditions, centrifugation parameters and storage conditions. <sup>120 121</sup> The biological material will be stored at Odense Patient data Explorative Network (OPEN) (biological material from Odense University Hospital) or at SHS (biological material from the other hospitals).		
††Only patients with CD when endoscopy cannot adequately evaluate inflammation.		
‡‡Primary endpoint for the individual diseases		
§§Corticosteroid-free remission. Clinical remission in patients using oral corticosteroids at baseline (pre) that have discontinued corticosteroids and in clinical remission at first follow-up.		
¶¶A reduction in complete Mayo score of $\geq 3$ points and $\geq 30\%$ from baseline (or a partial Mayo score of $\geq 2$ points and $\geq 25\%$ from baseline, if the complete Mayo score was not performed at the visit) with an accompanying decrease in rectal bleeding subscore of $\geq 1$ point or absolute rectal bleeding subscore of $\leq 1$ point.		
***Data for the Hurley stage reflect actual assessment. A patient's overall Hurley stage is the highest stage across all affected anatomical sites. Stage I is defined as the localised formation of single or multiple abscesses without sinus tracts or scarring, stage II as recurrent abscesses (single or multiple) with sinus tract formation and scarring and stage III as multiple abscesses with extensive, interconnected sinus tracts and scarring.		
†††All participants will be asked whether they have any complaints regarding or are known with diseases affecting the bowel, the skin, rheumatic complaints and so on, and if no to both questions they will not be asked to complete the relevant questionnaire.		
‡‡‡Biological response defined as a drop in CRP level of more than 25% or to the normal level among patients with an elevated CRP before treatment (higher than normal range). <sup>119</sup>		
ACR, American College of Rheumatology; ASAS, Assessment of Spondyloarthritis International Society; axSpA, axial spondyloarthropathy; BASDAI, Bath Ankylosing Spondylitis Disease Activity Index; BASFI, Bath Ankylosing Spondylitis Functional Index; BASMI, Bath Ankylosing Spondylitis Metrology Index; CCP/RF, cyclic citrullinated peptide/rheumatoid factor; CD, Crohn's disease; CRP, C-reactive protein; DAS, Disease Activity Score; DLQI, Dermatology Life Quality Index; EULAR, European League Against Rheumatism; FFQ, Food Frequency Questionnaire; HAQ, Health Assessment Questionnaire; HBI, Harvey-Bradshaw Index; HiSCR, Hidradenitis Suppurativa Clinical Response; HLA-B27, human leucocyte antigen; IBD, inflammatory bowel disease; K+, potassium; NA, not applicable; N+ sodium; NiU, non-infectious uveitis; NYHA, New York Heart Association; PASI, Psoriasis Area and Severity Index; PsA, psoriatic arthritis; PsO, psoriasis; SCCAI, Simple Clinical Colitis Activity Index; SDAI, Simplified Disease Activity Index; SES-CD, Simple Endoscopic Score for Crohn's Disease; SF12, Short Form Health Survey; SHS, Short Health Scale; STRIDE, Selecting Therapeutic Targets in Inflammatory Bowel Disease; SUN, Standardization of Uveitis Nomenclature for Reporting Clinical Data; TNF, tumour necrosis factor; UC, ulcerative colitis; UL, ultrasound; VAS, Visual Analogue Scale; y/n, yes/no.		

### Exploratory secondary (tertiary) outcomes

Additional exploratory outcomes will include biological measures, disease-specific disease activity measures as individual measure and combined scores as well as changes of these (including those measured by

physician/patients such as patients' health-related quality of life) at first clinical follow up<sup>53</sup> (week 14–16) (table 1). Other outcomes include changes in the use of concomitant medication, achievement of steroid-free remission, serious adverse events such as

hospitalisation and the need for surgery at first clinical follow-up (table 1).<sup>53</sup>

### Prognostic factors

#### Primary exposure variable

For the primary prognostic model, the primary exposure variables will be prioritised in the following order:

- ▶ The upper tertile of the sample (33.3% of the total sample), based on the ratio of fibre to meat intake, is associated with better treatment outcomes.
- ▶ The lower tertile of the sample (33.3% of the total sample) with respect to intake of red and processed meat and the upper tertile of the sample (33.3% of the total sample) with respect to intake of dietary fibres are independently associated with better treatment outcomes, and a potential interaction between them may further improve treatment outcomes.

#### Other (exploratory) exposure variables

- ▶ other lifestyle factors independently or combined (red and processed meat intake, vegetable intake, dietary fibre intake, cereal intake, gluten consumption, legume intake, red wine consumption, dairy product intake, amount of physical activity, smoking status, total protein/fat, protein/fat from red and processed meat, glycaemic index);
- ▶ pretreatment lifestyle-associated biomarkers;
- ▶ combinations of lifestyle factors and lifestyle-associated biomarkers;
- ▶ gene–environment interaction analyses;
- ▶ pretreatment levels of inflammatory molecules.

### Data management

The electronic questionnaire is in Danish. Participants will access the questionnaire by an electronic link which will be sent to their personal, electronic mailbox. All data will be stored in a secure research storage facility.<sup>54</sup> Information registered by clinicians and technicians will periodically be transferred from paper format to electronic format using either double entry of data or automated forms processing.<sup>55</sup>

No patient risks are foreseen as a direct result of this project. Clinicians will treat enrolled patients in the same fashion as non-enrolled patients. As a consequence, no data monitoring committee will be established.

### Statistical methods

Prognostic factor research was developed to aid health-care providers in estimating the probability or risk that a specific event will occur in the future. Hence, it has the potential to inform clinical decision-making.<sup>56</sup> Conceptually, a good prognostic model is one that functions for patients other than those from whom the data was derived.<sup>57</sup> Our intention is to use data obtained from this rigorously designed, prospective cohort study to explore our ability to predict clinical response across specific CID conditions (Y=primary endpoint) and to explore whether diets high in fibre AND low in red and processed meat (X=assessed at baseline) are an informative prognostic

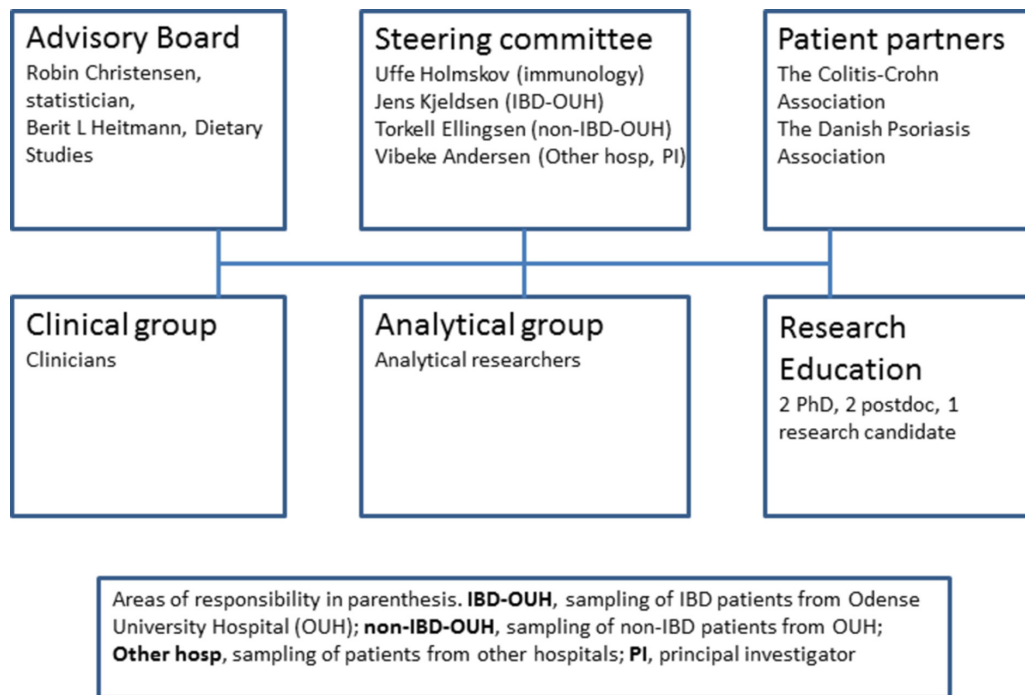
factor. Per default, the statistical models will include the specific CID condition and the clinical centre as fixed effects. Specific details will be part of the final statistical analysis plan (SAP). In terms of transparency, when reporting the multivariable models, the study will adhere to guidelines from the ‘Transparent Reporting of a multivariable prediction model for Individual Prognosis or Diagnosis’.

### Sample size considerations

Deciding sample size is a well-known difficulty with exploratory prognostic factor research studies. To obtain an adequate number of outcome events, we apply ‘the rule of thumb’, whereby 10 outcomes are needed for each independent variable. We plan to enrol 320 patients in total and we anticipate that 50% of these will experience a clinical response during the 14–16 weeks period after TNFi initiation.<sup>1</sup> With this in mind, and anticipating that we will see at least 160 events (ie, clinical response among the 320 patients), the study is sufficiently powered to explore the impact of as many as 16 independent variables including condition and clinical centre. Since using the ‘rule of thumb’ method to justify sample size is a debated practice, we went one step further and estimated the statistical power to detect differences between two dietary groups. For the contrast between groups and for a comparison of two independent binomial proportions (those with high-fibre and low-meat intake vs other) using Pearson’s  $\chi^2$  statistic, with a  $\chi^2$  approximation, with a two-sided significance level of 0.05 ( $P < 0.05$ ), a total sample size of 318—assuming an ‘allocation ratio’ of 1 to 2 (one-third)—has an approximate power of 0.924 (ie, >90% statistical power) if the anticipated proportions responding are 60% and 40%, respectively.

Statistical programming will be done using the software SAS V.9.4 (SAS Institute Inc., Cary, NC, USA), STATA or R, with transparent reporting of the source code used to analyse the data. Computational details will be available in the prespecified SAP. These will be finalised before data collection is complete. Our primary analysis set will be based on observations available at the time of study closure. In other words, we will consider ‘Data as observed’ to be our primary resource for statistical inference. However, for the purpose of sensitivity, multiple sensitivity analyses will be performed to assess the robustness of the primary analyses, including analyses based on the ‘Non-responder-imputation’ and multiple-imputation analyses, which are based on model-based approaches for missing data (these details will be available in the final SAP). A simplistic ‘null responder imputation’ would represent a conservative base case and is likely valid even if data is ‘missing not at random’,<sup>58</sup> as it assumes, and implies that patients have not improved or have worsened after entering the study.

No interim analyses will be performed. All reported P values will be two sided, and by default, these will not be adjusted for multiple comparisons. However, due to potential issues of multiplicity, as multiple statistical tests



**Figure 2** Organisation and patient research partners. IBD, inflammatory bowel disease.

will be performed in the study, we will interpret ‘statistically significant’ findings in the context of whether the 95% CI excludes outcomes that could be perceived as clinically important. We will use the following consistent language to describe effects that might appear as chance findings: “The prognostic factor appears to have little or no effect on the clinical outcome if the point estimate or the boundaries of the 95% CI lies between 0.80 and 1.25”. Thus, despite an apparently statistically significant finding ( $P < 0.05$ ), a relative point estimate within the range of 0.80 and 1.25 will not be considered a clinically meaningful effect.

The Food Frequency Questionnaire (FFQ) we use in the present study has been widely used in prospective cohort studies, including in European prospective investigations in the fields of oncology and chronic diseases.<sup>59 60</sup> It has been extensively used and evaluated in the Danish population, and results from different methods demonstrate consistency.<sup>61 62</sup> However, the FFQ is not without limits, in particular with respect to the lack of information on portion sizes.<sup>63 64</sup> We, therefore, modified the FFQ to capture information on portion size.<sup>63</sup> A second potential limitation relates to comprehensive questionnaire completion. However, in a pilot study of 10 hospital patients (50–70 years of age) the FFQ was completed within 40–50 min and no complaints were reported. The imprecision of the FFQ will lead to large CIs. The result will most likely lead to null results (rather than type 2 errors). The disease groups are expected to vary in several aspects such as age, gender and body mass index. We will, however, be unable to determine the potential effect of selective diet reporting on responders and non-responders.<sup>65</sup> On the other hand, studies have

suggested that dietary patterns are relatively stable among adults in the Danish population.<sup>66</sup> Due to study design and the limited number of participants, this study may not capture every lifestyle difference between responders and non-responders. Similarly, this study has only limited power to detect gene–environment interactions. To avoid potential type 2 errors, it is important that the results are replicated in other well-characterised patient populations using prospectively sampled dietary information. To further evaluate the robustness of the results, study results would preferably be replicated in cohorts from other countries.

### Project organisation

The study team is organised into three significant groups: a clinical research group (CRG), an analytical research group (ARG) (figure 2) and a steering committee (SC). The CRG includes specialists from gastroenterology, rheumatology, dermatology and ophthalmology who will be implicated in the clinical care and assessment of study participants. The ARG will be responsible for performing laboratory analyses on the collected biological material. Finally, the SC—whose members include Professor Uffe Holmskov, Professor Jens Kjeldsen, Professor Torkell Ellingsen and Professor Vibeke Andersen—are responsible for planning and organising the study within the appropriate legal framework, facilitating meetings for the three study groups and for scientific follow-up. The group as a whole, including clinicians and analysts, is responsible for the scientific results and budget.

Collaboration between patients and health professionals on research projects is a relatively new



phenomenon.<sup>67–69</sup> The involvement of patients in research (patient research partners (PRPs)) will ideally give a stronger voice to patients' views on research, specifically with respect to research priorities. Furthermore, individual patients and patient organisations can contribute to research study design, preparing educational material, discussing results, disseminating results and recruiting study participants. Recommendations on incorporating PRPs into research study processes suggest that they should be provided with relevant support and education. With this initiative, we were keen to gain experience with PRPs. Thus, this project was built with input from the Danish Colitis-Crohn's Association, represented by its director Charlotte Lindgaard Nielsen, the Danish Psoriasis Association, represented by its director Lars Werner and three individual patients with RA from one of the participating clinical departments.

The SC will hold telephone conferences every 2–4 weeks, but more often when necessary, and face-to-face meetings 3–4 times per year. Among participants, the SC will organise telephone conferences every 2–4 weeks, again more often when necessary, and face-to-face meetings at the time of enrolment and every year thereafter until the conclusion of the study.

### Perspectives

The use of prognosis research evidence at multiple stages is central to the process of translational research, with the ultimate goal of improving patient outcomes. Prognosis research includes various aspects of importance to healthcare professionals, enabling them to guide individual patients in terms of shared decision-making via overall prognosis, knowledge on important prognostic factors or models and subsequently (from randomised trial evidence) stratified medicine.<sup>56 70–72</sup> We anticipate that BELIEVE study will reveal prognostic factors of importance, including whether the diet of the patient is likely to interfere with the outcome of being prescribed a TNFi treatment. Hopefully, by combining various phenotype and genotype aspects into the prognostic models, BELIEVE study will add value to the long-term goal of achieving 'personalised medicine'.

We will seek to replicate findings that are identified as having prognostic value in other prospective cohorts, including from a planned study of CID cases from the Danish 'Diet, Health and Cancer' cohort and potentially from other cohorts with lifestyle data.<sup>73 74</sup>

### Dissemination of results to the public and scientifically

The target journal for the primary outcome will be a general medical journal directed at family physicians. Family physicians see patients with CID across the entire spectrum of disease. Moreover, lifestyle recommendations are an important element of general practice. Hence, although family physicians are not necessarily the primary decision-makers with respect to treatment of patients with CID, a role more ably assumed by

specialists, they have considerable influence on lifestyle decisions for patients with CID. Subsequently, other hypotheses will be analysed and manuscripts prepared (independent of findings), with the intention of submitting additional articles to specialised journals in the areas of nutrition, immunology, gastroenterology, rheumatology, dermatology and ophthalmology.

Authorship confers credit and has important academic, social and financial implications and therefore any authorship on manuscripts coming from BELIEVE study is associated with responsibility and accountability for the published work. Thus, we intend to follow the recommendations of the International Committee of Medical Journal Editors (ICMJE) to ensure that contributors who have made substantive intellectual contributions to a paper are given credit as authors, but also that contributors credited as authors understand their role in taking responsibility and being accountable for the published work.

The ICMJE criteria for authorship was designed to distinguish authors from other contributors based on the following four criteria: (1) substantial contributions to the conception or design of the work; or the acquisition, analysis or interpretation of data for the work; (2) drafting the work or revising it critically for important intellectual content; (3) final approval of the version to be published and (4) agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

In addition to the scientific reporting of results, major findings with translational implications will be communicated to health professionals, patient organisations, public health policy-makers and to the general public through various media and news activities.

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**Patient consent** Not required.

**Ethics approval** Written informed consent will be obtained from participants before participation in the study. The project has been approved by The Regional Scientific Ethical Committee (S-20160124) and the Danish Data Protection Agency (2008-58-035). The procedures followed are in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975 with later amendments.

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# Impact of red and processed meat and fibre intake on treatment outcomes among patients with chronic inflammatory diseases: protocol for a prospective cohort study of prognostic factors and personalised medicine

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